Conservation of Aquatic Biodiversity

Towards Empowering Fisheries Officers to Manage the Fish Stocks, Biodiversity & Environment of Kyoga basin Lakes

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Aquatic Systems of Uganda

Uganda is rich in aquatic resources. Up to 17 % of the country's surface area is covered by Aquatic systems comprising five major lakes; Victoria, Albert, Kyoga, Edward, George, about 160 minor lakes, an extensive river and stream system, dams and ponds. These aquatic systems are associated with extensive swamps (Fig.1).

Economic Importance of Aquatic Biodiversity

The aquatic systems are important sources of fish, the most affordable high quality protein for the people around those systems. The fishing industry provides employment for 0.5 to 1 million Ugandans. It is a major export commodity which currently ranks second to coffee in export earnings. In 1996fish fetched US $ 40 million in export revenue. There are indirect values that can be attached to the aquatic resources. Some of the fishes are of scientific value and are valuable in evolutionary and ecological studies. Some fish species are of medicinal value. The other components of the ecosystem such as algae and invertebrates provide food for fish and are important in sustaining a stable productive ecosystem. Fishes occupy most trophic levels and play a major role in the flow of energy in aquatic ecosystems. Maintenance of gene-species-ecosystem diversity has value implications beyond fish catch.

Non-target biodiversity concerns

Although there had been some efforts to manage the fisheries in most of the major aquatic systems, there was no significant effort to manage biodiversity and the fish habitat. During the mid 1980s, major ecosystem changes started manifesting themselves on Lake Victoria. Algal blooms and mass fish kills became frequent on the lakes. A comparison of data collected on Lake Victoria during 1960s with that of the 1990s showed that the concentration of phosphorus in the lake had doubled between 1960 and 1990 while that of silicon had decreased by a factor of 10 (Talling 1966, Hecky 1993, Mugidde 1993). Algal species composition had changed from dominance of diatoms (*Melosira)* to nitrogen fixing cyanobacteria some of which can produce phyto-toxins. Phytoplankton production had doubled and algal biomass increased four to five times (Mugidde 1993). This resulted in a four-fold decrease in water transparency. The diatoms which had disappeared were originally the most important food of *O. esculentus* (Graham, 1929) and this could have affected its stocks.

Changes in biotic communities also occurred among invertebrates. The composition and diversity of zooplankton community changed from dominance of larger types (calanoid copepods and cladocerans) to smaller types (cyclopoid copepods) probably due to changes in the types of their food and the abundance of organisms feeding on them (Worthington 1931, Rzoska 1956, Mwebaza-Ndawula 1994). This simplified the food-web and reduced the grazing efficiency of zooplankton (Lehman & Branstrator 1993).

The depletion of the trophically complex haplochromine community through and the changes in zooplankton community may have reduced the grazing pressure. This left much of the organic matter produced due to high algal growth in the lake unconsumed. Decomposition of this organic matter depleted the water column of oxygen and contributed to anoxia that was observed in parts of the lake deeper than 40m. This is thought to have driven haplochromines to shallower waters where they fell easy prey to Nile perch (Ogutu-Ohwayo & Hecky 1991). The expansion of the anoxic layer enabled only those organisms which can tolerate low oxygen conditions e.g. chironomid and chaoborid larvae, and the prawn, *Caridina nilotica* to proliferate.

The water hyacinth, *Eihhornia crassipes*, invaded Lake Kyoga in 1988 and Lake Victoria in 1989 (Twongo 1996). Water hyacinth occupied the shallow, sheltered bays which are breeding, nursery and feeding grounds for fish. The zone below extensive water hyacinth mats became deficient in oxygen which reduced habitable space for most fish and other aerobic organisms upon which fish feed, and affected aquatic biodiversity. Among the fishes, only *Protopterus aethiopicus* which can tolerate low oxygen conditions flourished under water hyacinth mats. The invertebrate community under hyacinth was again dominated by low oxygen tolerant types, chaoborids and chironomids (Wanda 1997). Whereas hypoxia had driven the deep-water species to shallower waters, the anoxic conditions created by water hyacinth were driving them out of their shallow water refuge.

Examination of paleolimnological information (Hecky 1993) suggests that the changes in the physico-chemical conditions and lake productivity processes in Lake Victoria started at the turn of the century as human activities in the catchment areas. At that time, certain species of algae increased while others declined. These changes however, accelerated during the 1960s.

Global Commitment to Biodiversity Conservation

The threat to global biodiversity culminated into one of the most important international agreements, The Convention on Biological Diversity, (CBD), prepared in Rio de Janeiro in 1992. In ratifying the CBD, governments agreed to take actions to: conserve biological diversity; ensure sustainable use of its components; and ensure fair and equitable sharing of benefits from genetic resources. The changes in biodiversity that have occurred in Lake Victoria due to human exploitation, environmental degradation and introduction of exotic species are of direct application to the CBD. The general measures for conservation and sustainable use are given in Article 6 of the CBD. Some of the key areas of intervention that would be applicable to the Lake Victoria situation are: biodiversity identification and monitoring (*Article 7*); *In-situ* conservation (*Article 8*); *Ex-situ* conservation; (*Article 9*); Sustainable use (*Article 10*); Public education (*Article 13*); Impact Assessment (*Article 14*); Exchange of information (*Article 17*); and Technical and scientific cooperation (Article 18).

The concern about the depletion of the biodiversity of Lake Victoria, and the potential, social and economic consequences of this loss has led to a number of regional and national efforts to conserve and sustainably use aquatic resources, especially Lake Victoria. This process has involved:

- Sustainable use of emerging fisheries;
- *Ex-situ* conservation through captive propagation;
- Conservation of selected ecosystems and habitats in which endangered species are surviving;
- Conservation of species in specific habitats and ecosystems;
- Determining the biological and ecological characteristics especially of rare and endangered species to guide selection of populations for conservation efforts;
- Genetic characterization especially of endangered and that of those that are likely to impact them to guide selection of population for conservation and genetic similarities and differences;
- Managing the irnpact of introduced species;
- Managing the impact of water hyacinth infestation
- Controlling degradation of the aquatic environment;
- Enhancement of stocks of endangered fish species and promoting aquacultural species through fish farming;
- Conserving representative samples of existing biodiversity in zoos, aquaria and museum;
- Improving acquisition, packaging and dissemination of information;

Efforts to conserve fishes through *Ex-situ* captive propagation

The original efforts to conserve the biodiversity of threatened species of Lake Victoria was to rescue endangered cichlids and breeding them in North American Aquaria and Zoos with the hope of reintroducing them into Lake Victoria. This was a collective effort of the Lake Victoria Fish Species Survival Program which was a consortium of North American Museums in collaboration with FIRRI, KMFRI, and TAFIRI. This effort involved collection of fish that were considered threatened in Lake Victoria and keeping them in captivity until the populations of the Nile perch had been reduced to levels where these species could be re-introduced into the lakes (Ribbink, 1987). Under this arrangement, haplochromines and *O. esculentus*, were collected from Lake Victoria and associated water bodies and flown to Europe and North America.

There were a number of problems with this option. At that time, the plan was that the species maintained in captivity could be re-introduced into the lakes from which they had been collected after the Nile perch populations had been reduced. There was however, no hope of completely removing Nile perch from Lake Victoria and the other lakes (Kyoga and Nabugabo) to which the predator had been introduced. Besides, this would be economically undesirable because of the large economic benefits that had been realized from Nile perch catches in Lake Victoria. The other problem was that cichlids especially haplochromines are known to undergo rapid genetic differentiation. The species kept abroad would probably have changed by the time of re-introduction. There was also a limit to the number of species, which could be protected by this approach. This method was therefore of limited value.

Conservation of the Diversity of Ecosystems

One of the mechanisms of addressing biodiversity concerns of Lake Victoria is to identify and conserve the diversity of ecosystems. The diversity and the status of ecosystem health within and between the lakes containing Victorian fish fauna have been characterized on the basis of biotic and physico-chemical parameters. This has covered the main Lake Victoria and the satellite lakes within the Victoria and Kyoga lake basins. The satellite lakes that have so far been examined include Nabugabo lakes, Koki lakes and Kyoga satellite lakes. (Fig.1). The areas examined within the different aquatic systems include; rocky outcrops, macrophyte and papyrus wetlands, river mouths.

Some of the lakes, especially those which have been encroached upon by human activities have been observed to manifest signs of eutrophication by having low secchi depth and high Chl-a concentration (Fig. 2). These criteria are being used to select aquatic systems and habitats, which would be valuable for biodiversity conservation. Generally, lakes, which are protected from human encroachment such as Lake Agu (among the Kyoga satellite lakes), are very valuable in biodiversity conservation and are being recommended for protection. The lakes that are showing signs of eutrophication are being recommended for rehabilitation.

Almost all the native non-cichlids which occurred in the main lakes Victoria and Kyoga before the Nile perch upsurge have been encountered in a number of the satellite lakes. The satellite lakes are at different stages of human interference with some of them little or not disturbed at all. Those with high biodiversity values have been recommended for protection.

Aquatic habitats with macrophytes, near-shore areas, rocky areas and river mouths support high diversity of aquatic flora and fauna. Overall, the diversity of fish and invertebrates decreased with distance from the shore (Fig.3). Protection of near-shore areas and other areas supporting high biodiversity will be valuable in conservation of aquatic biodiversity of Lake Victoria.

Nile perch cannot survive under low oxygen conditions (Fish, 1956) such as those in papyrus swamps. Some native species, which can survive under these conditions, can be protected from Nile perch predation. Papyrus swamps and fringing wetlands have been observed to provide refuge from Nile perch (Chapman *et al* 1996). They also serve as barriers to movement of Nile perch between adjacent water bodies. It has therefore been recommended that papyrus swamps and vegetation along and between affected lakes should, not be cleared to protect species in them and to stop the spread of Nile perch into those lakes. For instance, the swamps separating lakes Manywa and Kayugi from Lake Nabugabo, and Lake Kayanja from Lake Victoria and those separating the Kyoga satellite lakes from the main lake have been recommended for protection to prevent the spread of Nile perch into those lakes.

Studies made elsewhere show that rocky areas are important refugia for fish and other aquatic organisms. In Lake Tanganyika, where there are *Lates* spp, most haplochromines are confined to rocky areas where they are able to evade predation by *Lates* species (Fryer & Iles 1972). In Lake Victoria, rock-dwelling species have been least affected by Nile perch predation (Ogutu-Ohwayo 1990b, Seehausen 1999, Witte *et al* 1992a, b). Rocky areas are therefore important refugia for haplochromines and other endangered species.

A major conclusion from the above studies is that protection of refugia is foreseen as one of the most effective methods for conserving fish species diversity.

Conservation of species diversity

Information has been collected on species diversity of algae, macrophytes, micro and macro invertebrates, fish, lower and higher vertebrates, in Lake Victoria and the satellite lakes. This includes composition, abundance, distribution and size structure. The diversity of these organisms varied between the ecosystems examined. Again, less disturbed lakes have been observed to have higher species diversity compared to more disturbed ones.

Biological and ecological information on key endangered taxa notably, the native tilapiines, (*Oreochromis esculentus* & *O. variabilis*), *L. victorianus, Bagrus docmak* and haplochromines has been collected. The trophic ecology especially of haplochromines has also been examined. Some of these have been observed to vary considerably between lakes. For instance the relative importance, and biological characteristics of *O. esculentus* has been observed to vary between the lakes examined (Table 1). These differences have been used to determine and to recommend stocks of *O. esculentus* which should be protected.

Many of the trophic groups of haplochromines that disappeared from lakes Victoria, Kyoga and Nabugabo have been observed to survive in Kyoga satellite lakes (Fig. 4). These lakes would be very important in conservation and understanding of the trophic diversity especially of haplochromines that existed in lakes Victoria and Kyoga some of which disappeared before they were adequately studied.

Conservation of genetic diversity

The genetic variability of haplochromines, native tilapiines, introduced tilapiines and *L. victorianus* have been examined to guide conservation efforts. The populations of *L. victorianus* showed marked genetic differences by location. There are also clear differences among populations of native tilapiines compared to introduced tilapias. Nile tilapia is least differentiated while *O. esculentus* exhibited the highest level of population sub-division. These observations suggest that conserving genetic diversity of *L. victorianus* and *O. esculentus* will require protecting many and not just single populations.

The genetic status of *O. niloticus* which has displaced the native tilapiines in lakes to which it has been introduced was evaluated. *O. niloticus* hybridizes with the two native tilapiines. *O. niloticus,* is ecologically versatile and genetically superior to the other tilapiines of the Victoria and Kyoga lake basins. This makes *O. niloticus* a threat to continued existence of the native tilapiine species. Conservation of the gene pool of the native tilapiines will depend upon ensuring complete separation of remnants of the native tilapiine population from *O. niloticus.* Some of the satellite lakes within the Victoria and Kyoga Lake basins contain the only population of native tilapiines which have not been contaminated by *O. niloticus*. It has been recommended that measures should be undertaken to safeguard against entry *O. niloticus* into these lakes.

Managing the impact of exotic Nile perch

A number of studies have been carried out to determine the impact of predation by Nile perch on other fishes. These studies showed that Nile perch had contributed greatly to reduction in stocks of fishes especially haplochromines in Lake Victoria. Recovery or improvement in stocks of endangered species would depend upon reduction in Nile perch stocks. Data collected from Lake Kyoga (Ogutu-Ohwayo 1994) shows that stocks of haplochromines had increased since 1988 (Fig. 5). This coincided with decline in Nile perch stocks and expansion of vegetation cover due to the spread of water hyacinth. This suggested that reduction in Nile perch stocks and increase in cover would allow stocks of haplochromines and other fishes to recover. Selective exploitation of Nile perch especially at the time when it feeds heavily on other fishes could reduce predation pressure on those fishes and help improving their stocks. This is however not foreseen as an appropriate option for protecting endangered species due to the high economic value of Nile perch.

Control of water hyacinth

Biodiversity has also been affected by water hyacinth infestation and from efforts to control of water hyacinth. It has been observed that the zone under large expanses of water hyacinth are devoid of oxygen and are therefore poor in biodiversity. However, narrow, adequately oxygenated water hyacinth fringes supports high biodiversity apparent through acting as refugia. Measures have been taken to control water hyacinth on Lake Victoria. This involved biological control using two weevil types *Neochetina bruchi* and *N. eichhornia* mechanical and manual removal at strategic areas such as the hydropower station at Jinja, the Wagon Ferry Terminal at Portbell, water extraction points and fish landings. Water hyacinth mats have also been displaced through ecological succession by native plants especially hippo grass, *Vossia cuspidata*. It has been observed that proliferation of water hyacinth is related to nutrient levels. Control of nutrient inputs to Lake Victoria is expected to contribute to control of water hyacinth.

Conservation and stock enhancement through aquaculture

One of the options being developed to avail some of the threatened food fishes has been to introduce them into fish farming. Technologies are being developed to introduce *O. esculentus* and *L. victorianus* in aquaculture.

Conserving endangered species in zoos, aquaria and museum

Some of the aquatic flora and fauna will be lost irrespective of any degree of protection. Representative samples of existing biodiversity are therefore being kept as preserved specimens in museum and other are being maintained as live specimens in aquaria and zoos at research and selected educational institutions.

Improving acquisition, packaging and dissemination of information

Creating an informed society has been recognized as a prerequisite to conservation efforts. Information is being made available to stakeholders at different levels. This is involving production and distribution of books, booklets, charts, facts sheets, brochures, geo-referenced maps to be used in biodiversity conservation efforts. Information dissemination activities are also being carried out through workshops aimed at increasing awareness of extension agents, communities, students in primary, secondary and tertiary educational institutions.

Conclusions

Considerable progress has been made in incorporating biodiversity concerns in management of the fisheries of Lake Victoria and associated water bodies. There is also considerable amount of information to guide management of biodiversity. Some of the areas needing attention include: having clear national and regional policies on biodiversity conservation and management; strengthening co-ordination of institutions dealing with aquatic resources management and biodiversity conservation; ensuring that there is adequate data to guide formulation of policies, laws and regulations; ensuring that there is adequate community participation and commitment to biodiversity conservation; and ensuring that the funds are allocated to biodiversity conservation efforts.

Interventions to conserve Aquatic Biodiversity

- Avoid clearing aquatic macrophytes in and along the lakes;
- Regulate fishing within rocky and vegetation refugia;
- Declare some lakes or habitats into protected areas e.g marine parks;
- Concentrate fishing effort on Nile perch of size that feed on other fishes;
- Propagate and maintain endangered species in aquaria, dams and ponds;
- Preserve and keep specimens of existing species in museums.

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Tables:

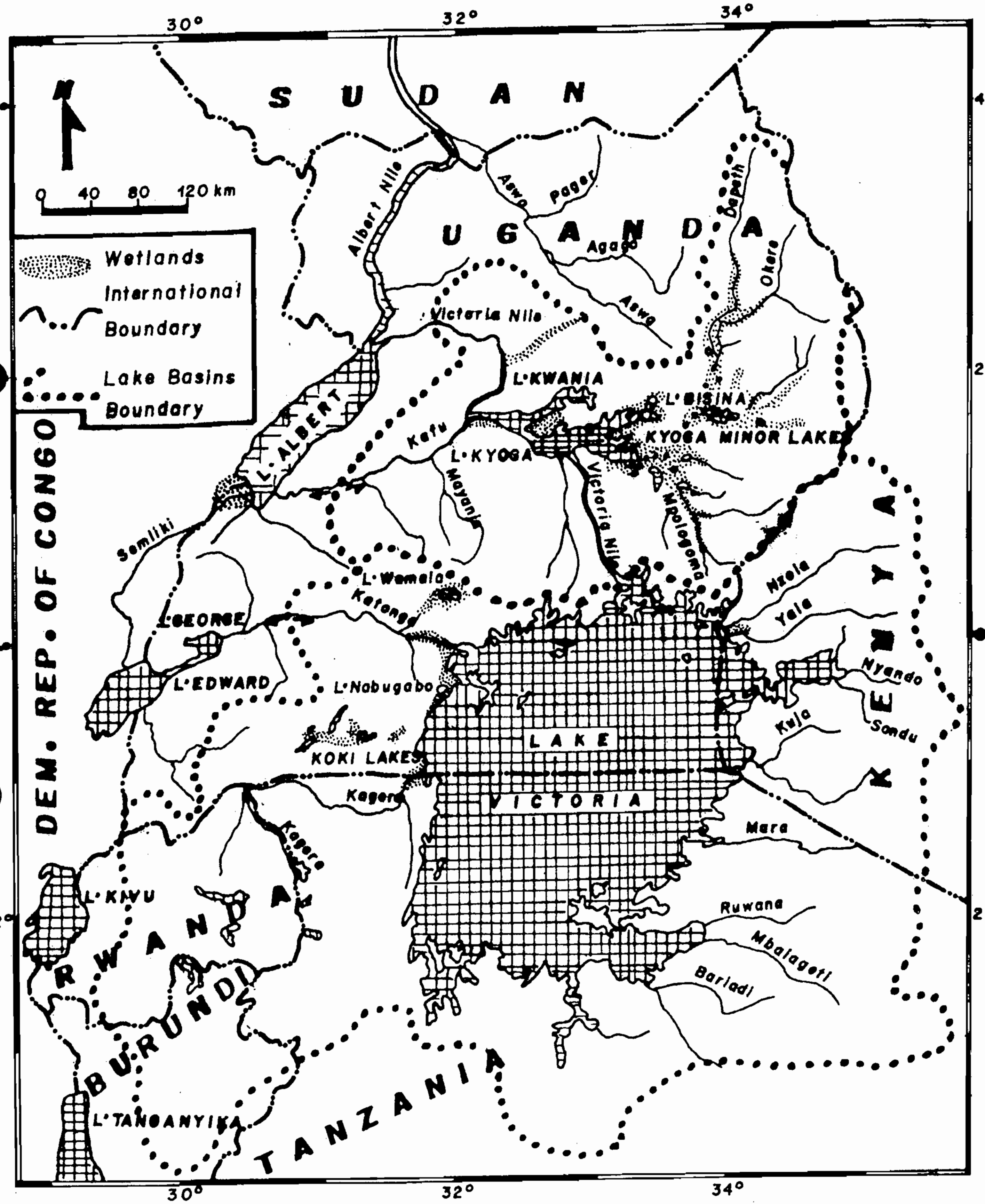
Table 1. Population characteristics of *O. esculentus* in different lakes of the Victoria and Kyoga Lake basins. Based on data in Nagayi, (1999).

Parameter	Lake					
	Kayanja	Kayugi	Mburo	Kachera	Kawi	Lemwa
Contribution to fish catch % by number	23.3	6.7	33.5	20.4	3.4	1.5
Maximum size (cm)	28.0	38.7	26.0	28.5	25.0	17.0
Size at 50% maturity (females)	15.4	20.5	16.8	17.0	15.6	17.0
Condition factor	1.5	1.9	1.8	1.9	2.0	1.8
Females per male	0.9	1.0	1.5	0.8	0.5	0.7

Figure Captions

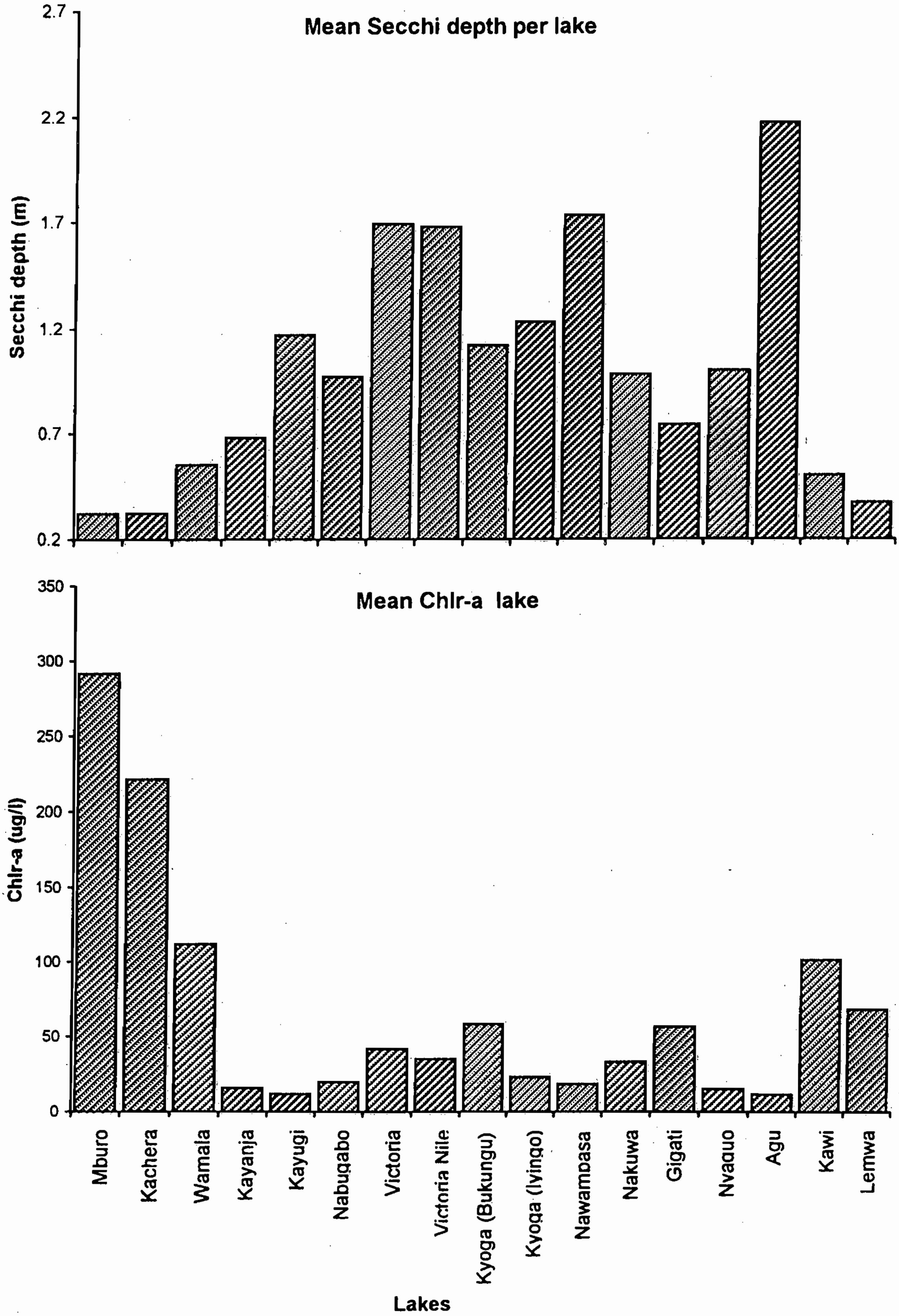
Figure 1.	A map Uganda showing the main aquatic systems and that of the Victoria and Kyoga lake basins.
Figure 2.	Secchi depth and chlorophyll concentration in different lakes in the Victoria and Kyoga lakes basins.
Figure 3	Distribution of fish in the nearshore area of Napoleon Gulf of Lake Victoria. Data taken in 1996.
Figure 4	Comparison in the number of haplochromine trophic groups in the Victoria and Kyoga lake basins.
Figure 5.	Increases in catch rates of haplochromines in Lake Kyoga following heavy exploitation of Nile perch.

Fig. 1



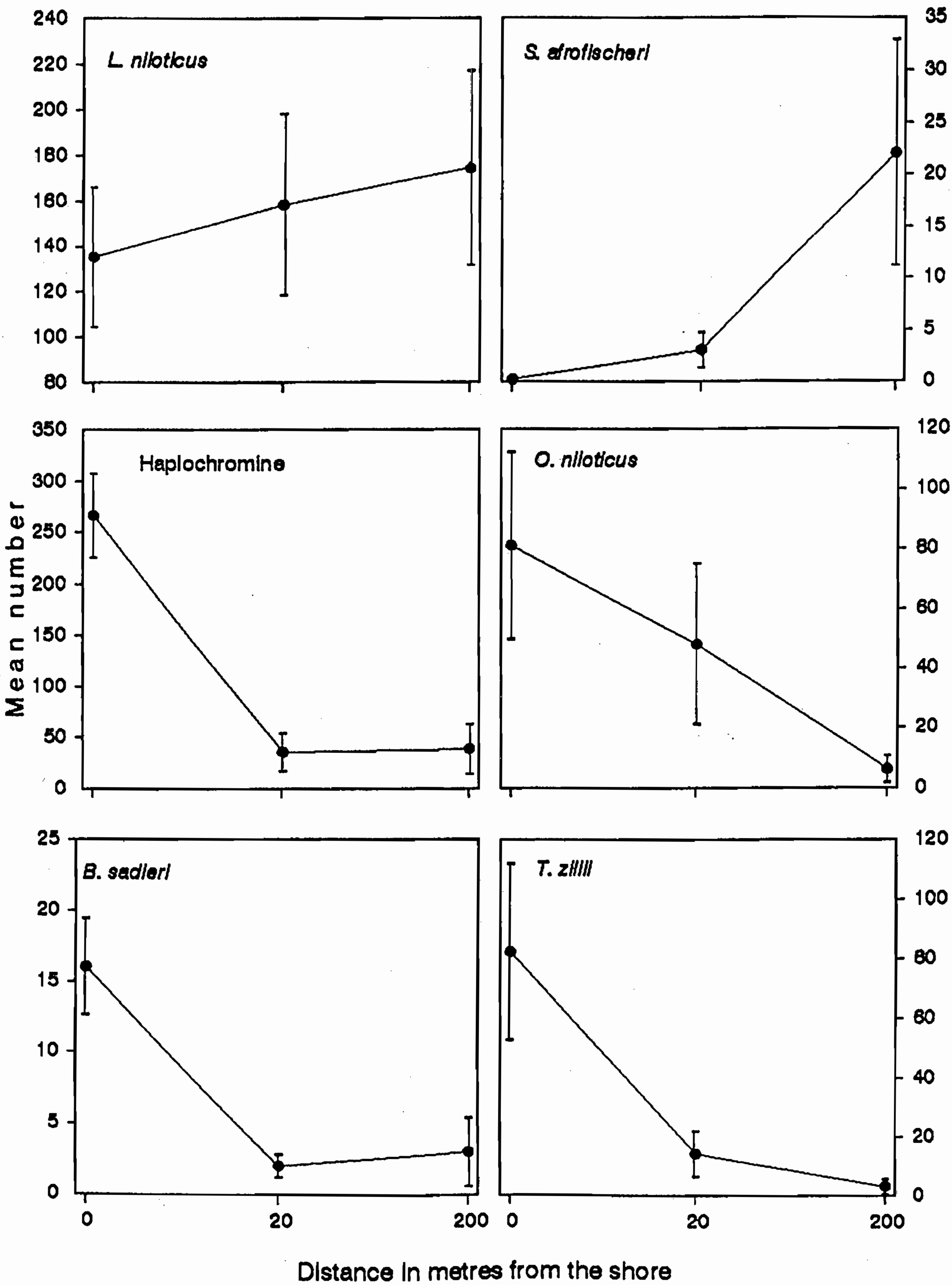
30°
32°
34°
4°
2°
SUDAN
UGANDA
N
0 40 80 120 km
Wetlands
International Boundary
Lake Basins Boundary
DEM. REP. OF CONGO
Albert Nile
Aswa
Pager
Agago
Dopeth
Okere
Victoria Nile
L. ALBERT
L. KWANIA
L. BISINA
KYOGA MINOR LAKES
Kafu
L. KYOGA
Mayanja
Mpologoma
Semliki
L. Wamala
Katonga
L. GEORGE
L. EDWARD
L. Nabugabo
KOKI LAKES
Kagera
LAKE VICTORIA
Nzoia
Yala
Nyando
Sondu
Kuja
KENYA
Mara
Ruwana
Mbalageti
Bariadi
L. KIVU
RWANDA
BURUNDI
L. TANGANYIKA
TANZANIA

Fig. 7



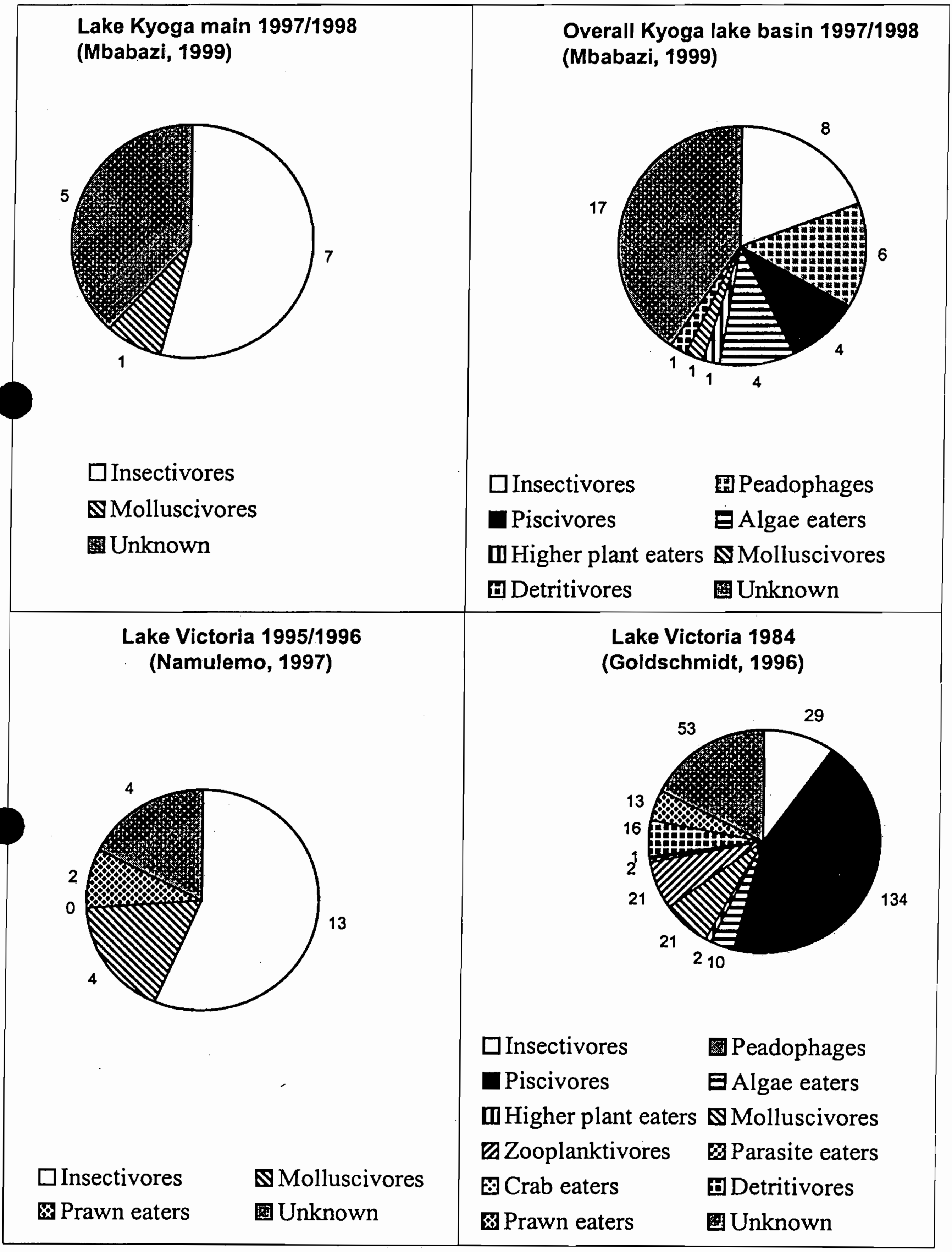
Mean Secchi depth per lake
Secchi depth (m)
2.7
2.2
1.7
1.2
0.7
0.2
Mean Chlr-a lake
Chlr-a (ug/l)
350
300
250
200
150
100
50
0
Mburo
Kachera
Wamala
Kayanja
Kayugi
Nabugabo
Victoria
Victoria Nile
Kyoga (Bukungu)
Kyoga (Iyingo)
Nawampasa
Nakuwa
Gigati
Nyaguo
Agu
Kawi
Lemwa
Lakes

Fig. 8



240
220
200
180
160
140
120
100
80
L. niloticus
35
30
25
20
15
10
5
0
S. afrofischeri
350
300
250
200
150
100
50
0
Haplochromine
120
100
80
60
40
20
0
O. niloticus
25
20
15
10
5
0
B. sadleri
120
100
80
60
40
20
0
T. zillii
Mean number
0
20
200
0
20
200
Distance in metres from the shore

Fig. 9



Lake Kyoga main 1997/1998
(Mbabazi, 1999)
5
7
1
Insectivores
Molluscivores
Unknown
Overall Kyoga lake basin 1997/1998
(Mbabazi, 1999)
8
17
6
4
1
1
1
4
Insectivores
Peadophages
Piscivores
Algae eaters
Higher plant eaters
Molluscivores
Detritivores
Unknown
Lake Victoria 1995/1996
(Namulemo, 1997)
4
2
0
13
4
Insectivores
Molluscivores
Prawn eaters
Unknown
Lake Victoria 1984
(Goldschmidt, 1996)
29
53
13
16
1
2
21
134
21
2
10
Insectivores
Peadophages
Piscivores
Algae eaters
Higher plant eaters
Molluscivores
Zooplanktivores
Parasite eaters
Crab eaters
Detritivores
Prawn eaters
Unknown

Fig. 10

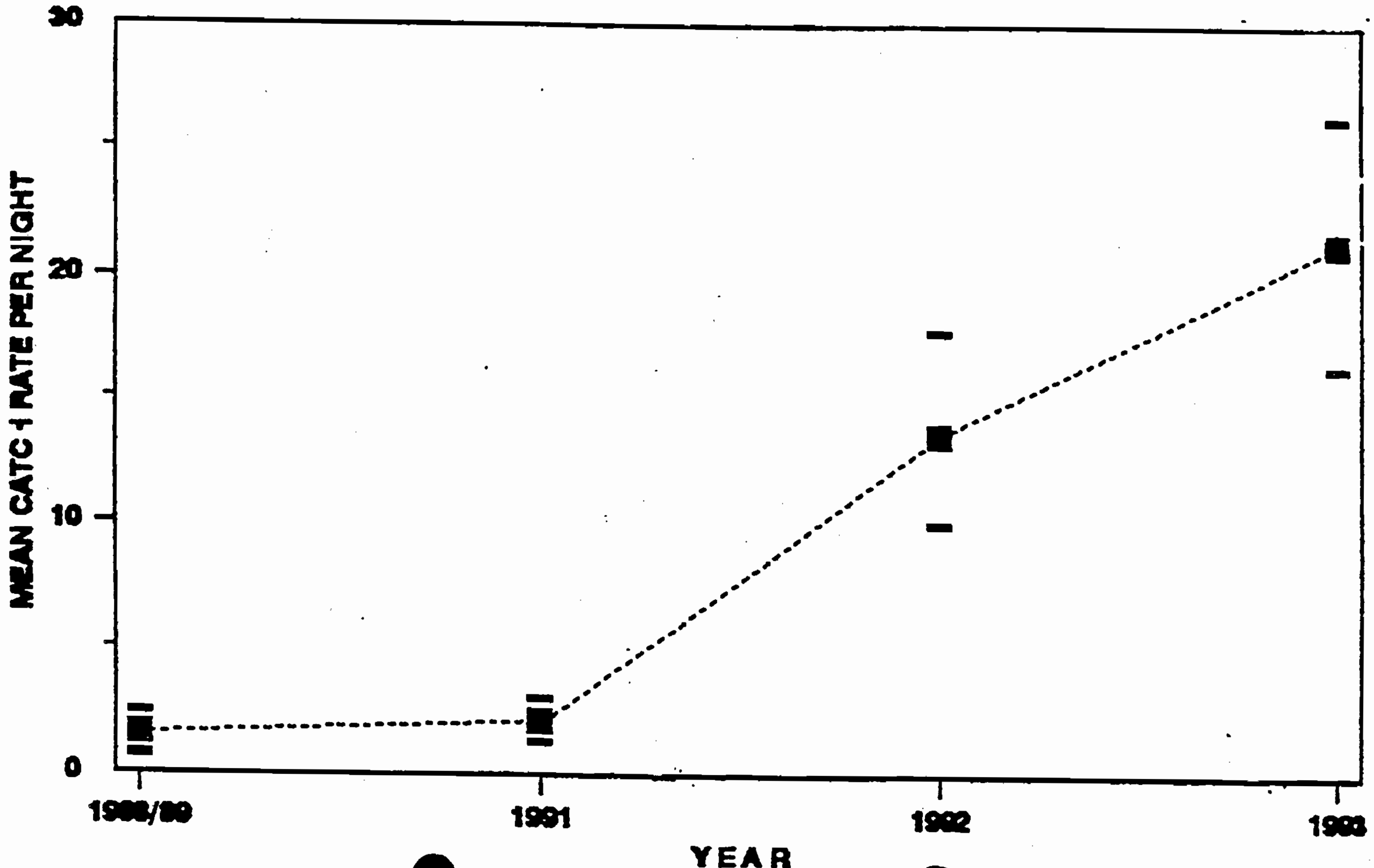
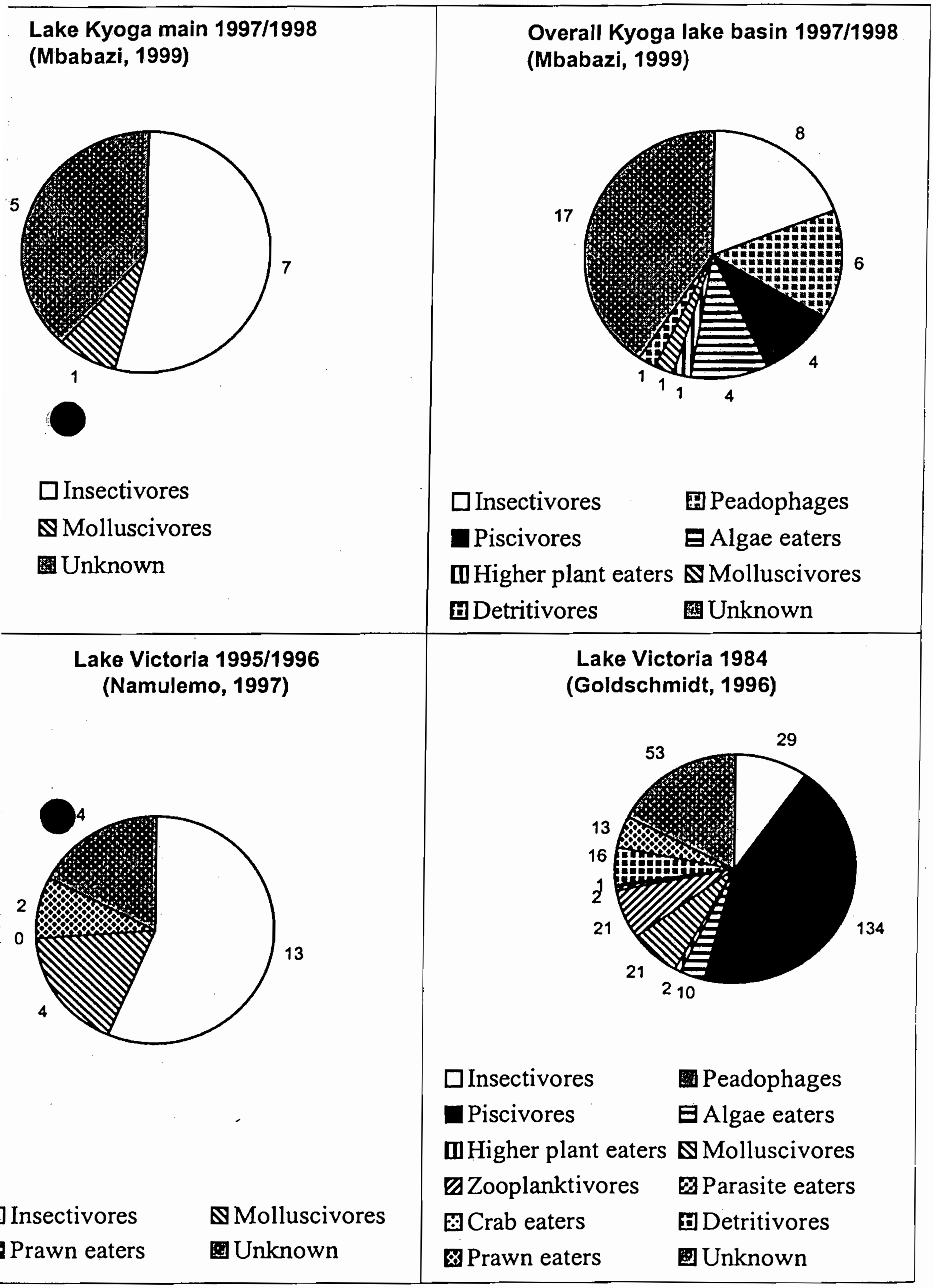


Fig. 9



Lake Kyoga main 1997/1998
(Mbabazi, 1999)
5
7
1
Insectivores
Molluscivores
Unknown
Overall Kyoga lake basin 1997/1998
(Mbabazi, 1999)
8
17
6
4
1
1
1
4
Insectivores
Piscivores
Higher plant eaters
Detritivores
Peadophages
Algae eaters
Molluscivores
Unknown
Lake Victoria 1995/1996
(Namulemo, 1997)
4
2
0
13
4
Insectivores
Prawn eaters
Molluscivores
Unknown
Lake Victoria 1984
(Goldschmidt, 1996)
53
29
13
16
1
2
21
134
21
2
10
Insectivores
Piscivores
Higher plant eaters
Zooplanktivores
Crab eaters
Prawn eaters
Peadophages
Algae eaters
Molluscivores
Parasite eaters
Detritivores
Unknown

Fig. 10